Offline Analysis of H4 Beam Line Instrumentation Data

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Overview

- Offline event tree.
  - Tool, raw beam line data —> match instrumentation event-wise to general trigger.
  - ROOT file for easy analysis.

- Beam profile monitor (XBPF) performance.
  - Hit multiplicities.
  - Multiple and single hit efficiencies.

- Momentum reconstruction analysis.
  - Correction to relative position XBPF.

Offline Event Tree

What is the Event Tree

- Tool to make event-by-event analysis of all beam line instrumentation more straightforward.
- C++ code, matches in time 34 variables by spill —> then by event.
- Done by defining a **search window** around general trigger.
- Identify the **same event** passing through **all detectors**.

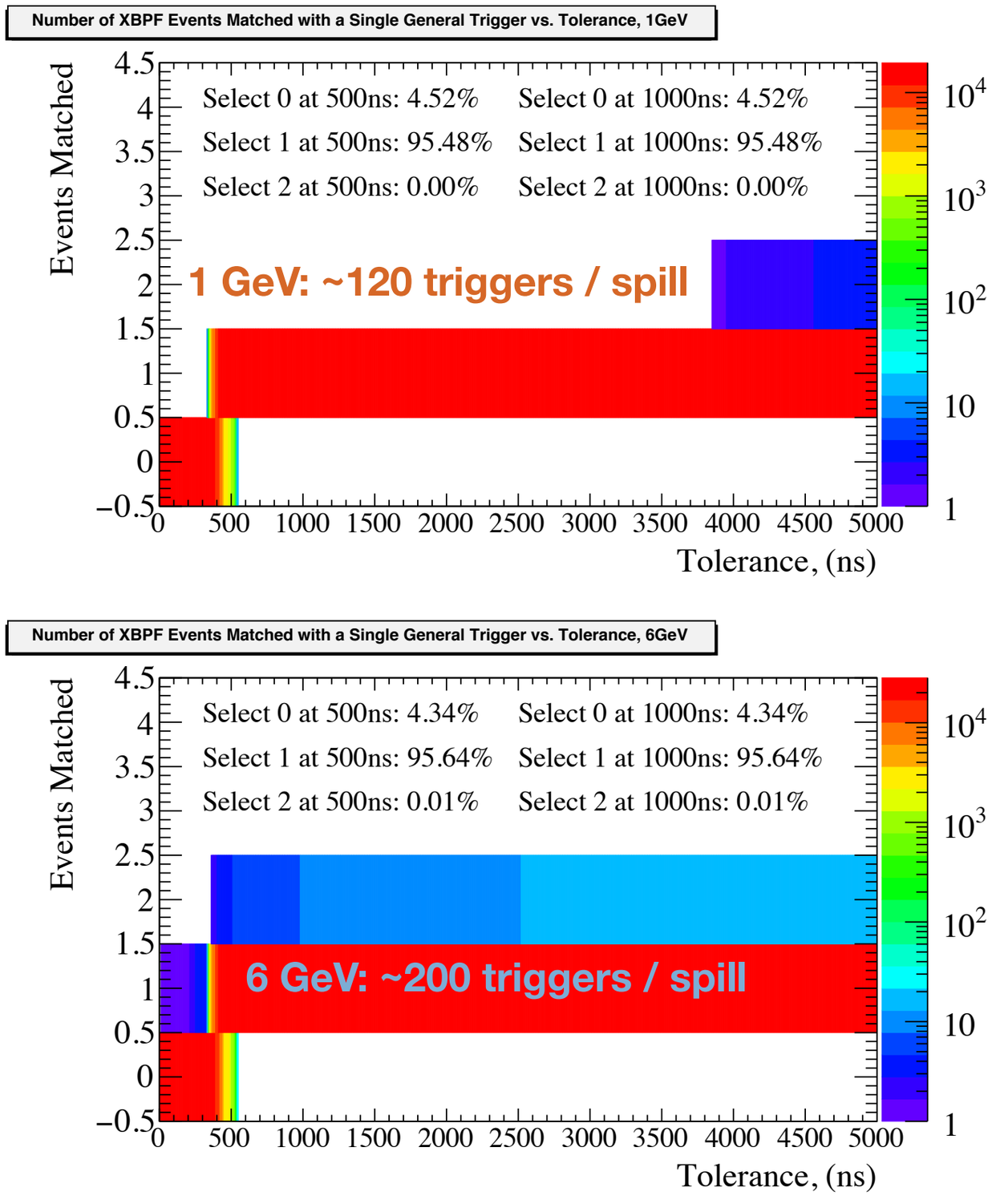
- Each tree entry <-> 1 event (general trigger).
  - Event level variables: e.g. Time of flight, reconstructed momentum, etc.
  - Associated spill level variables: e.g. Cherenkov pressures, collimator positions, etc.
- Assigned ‘event rank,’ golden, silver.

Key component**, size of search window.**

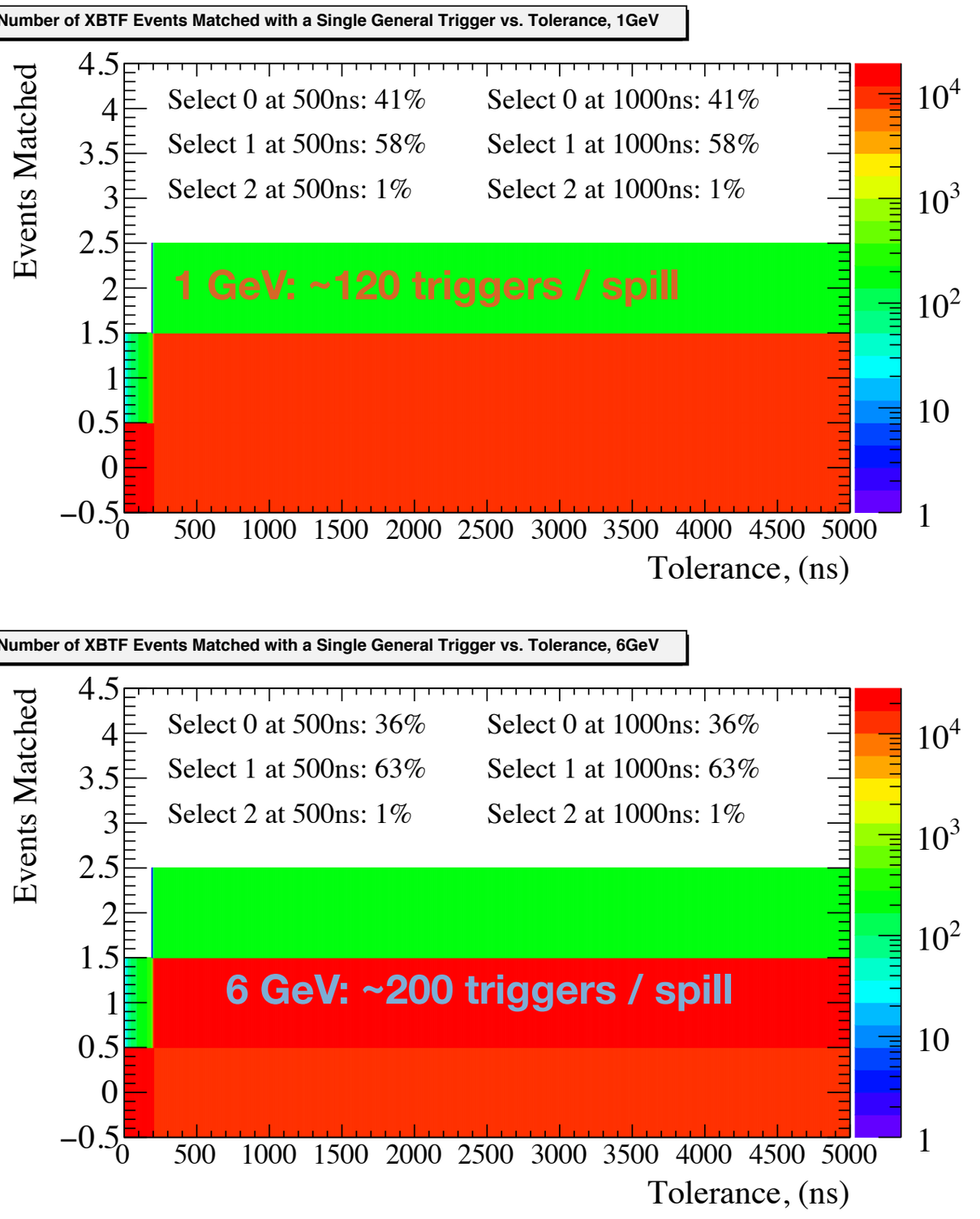
Back of envelop guess -> 500 ns.

Timing Tolerance with General Trigger

XBPF702 (Triggered)



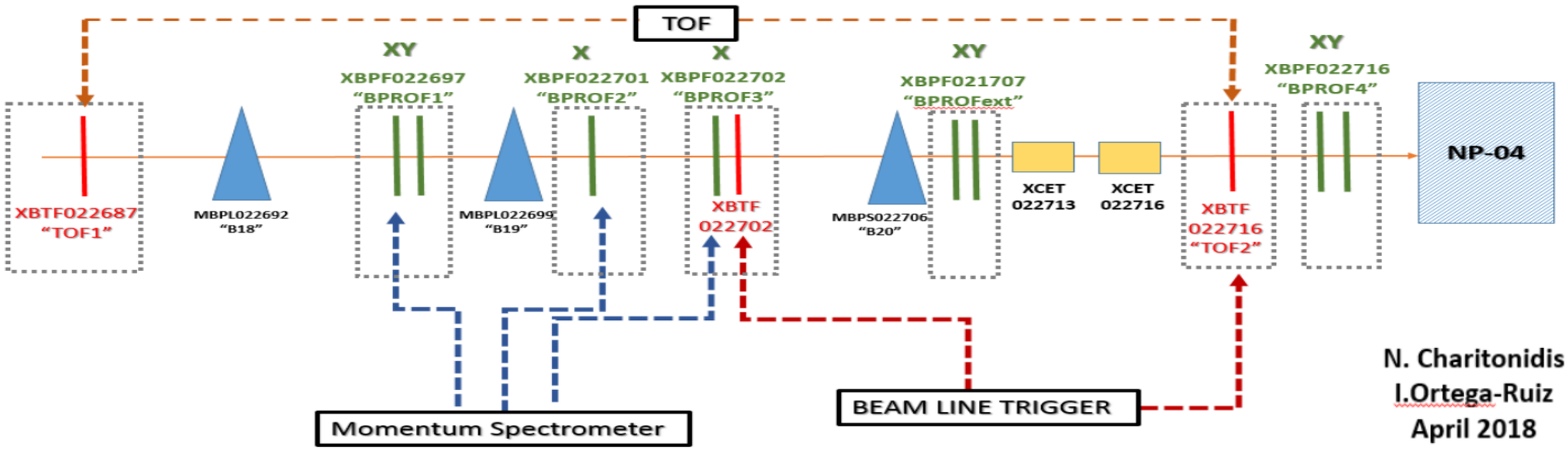
XBTF687A (Not triggered)



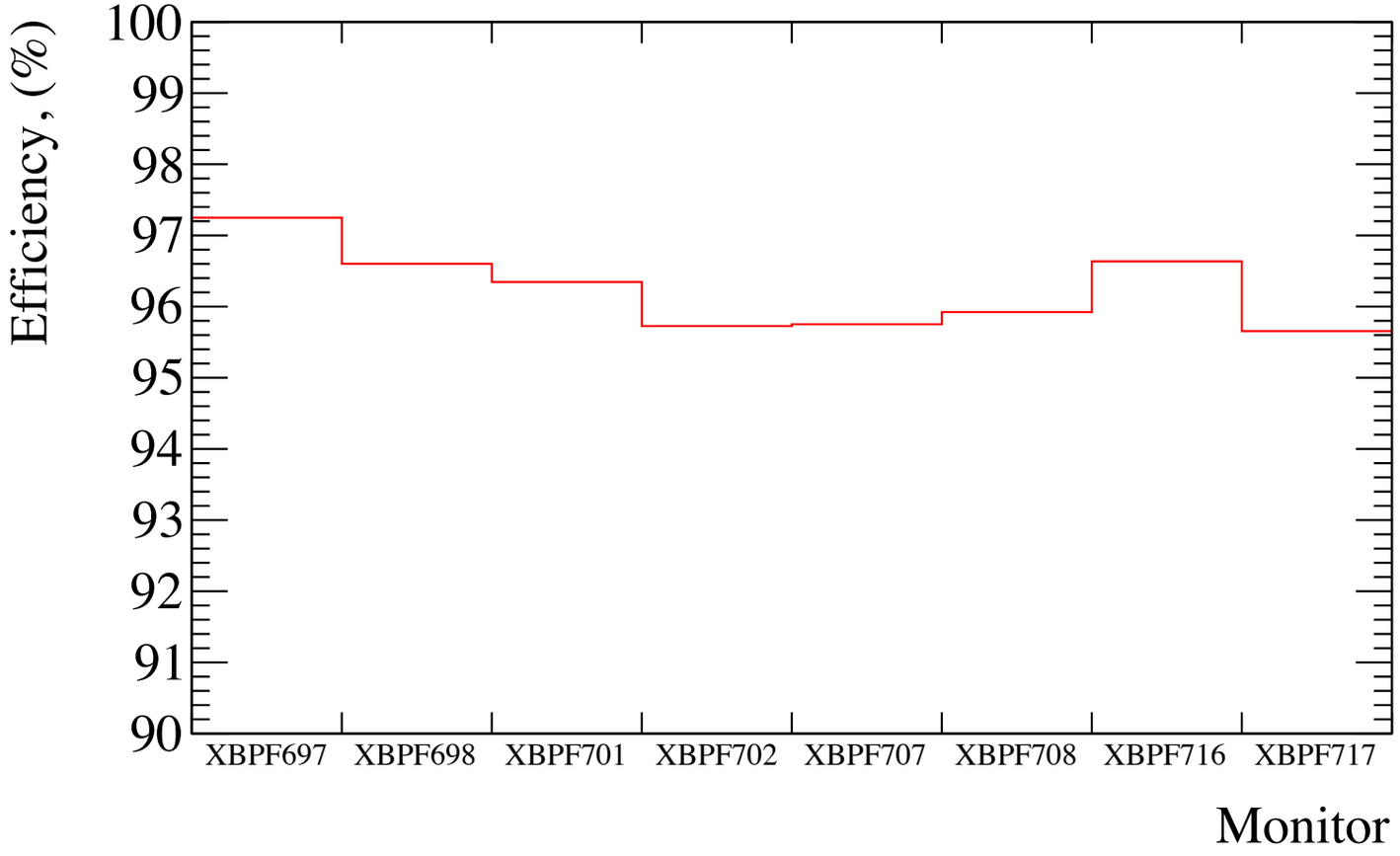
500 ns was a good choice! Don’t loose events, don’t double count.

Beam Profile Monitor Efficiencies

XBPF Efficiencies



Profile Monitor Efficiency

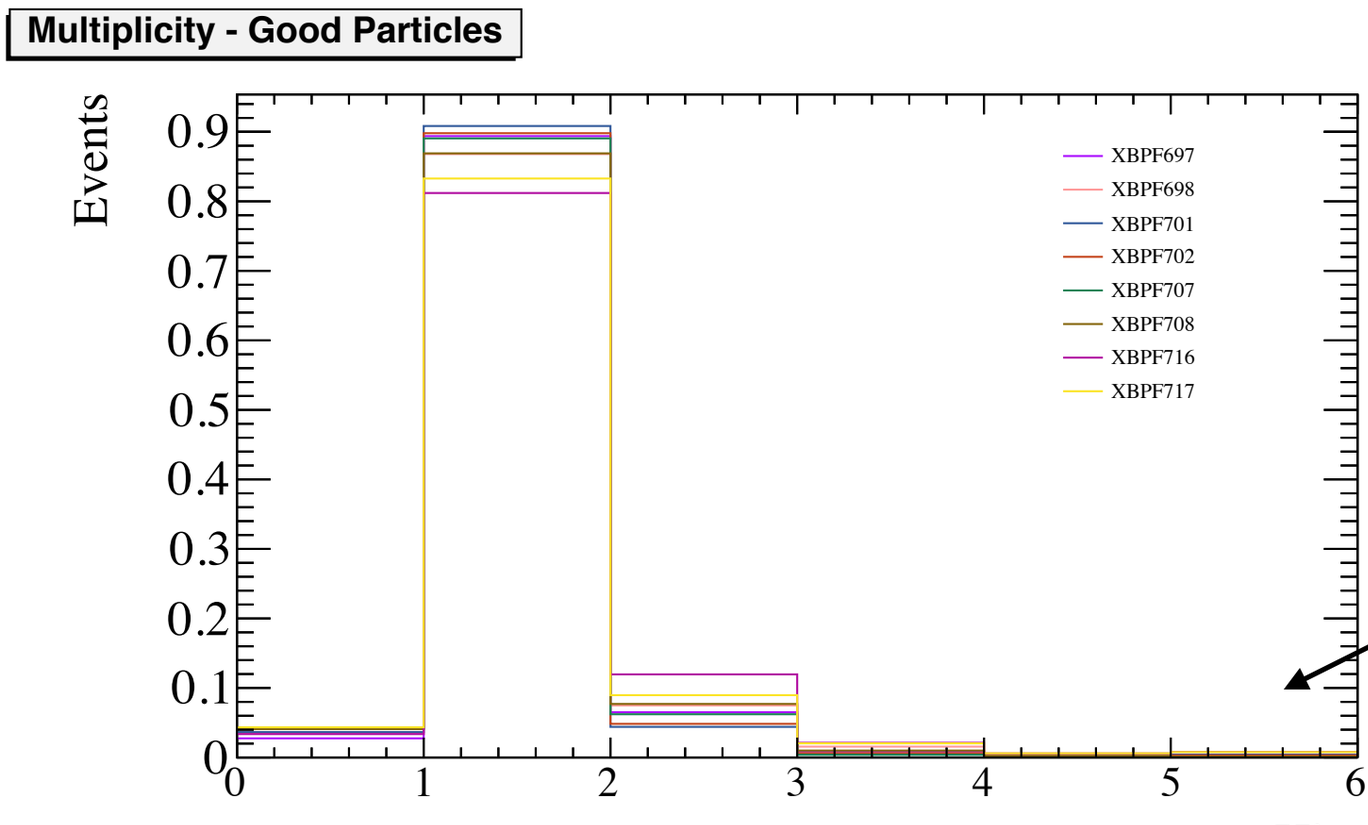


23 hours of data at various energies.

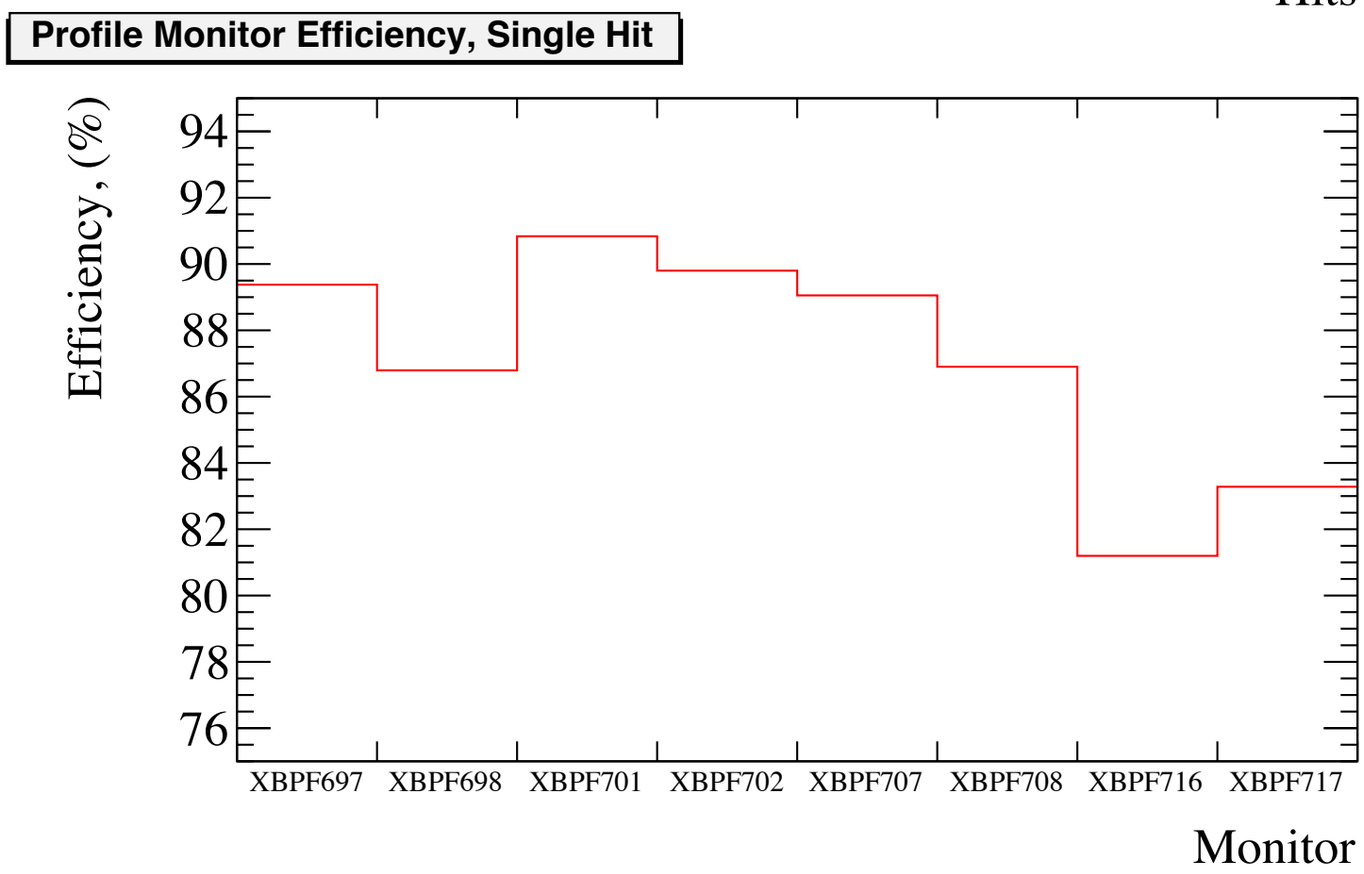
Efficiency = # triggered events with at least 1 channel hit / total number of general triggers

Measured XBPF efficiency > 95.5 % for all momenta.

Multiple hits / Triggered Event



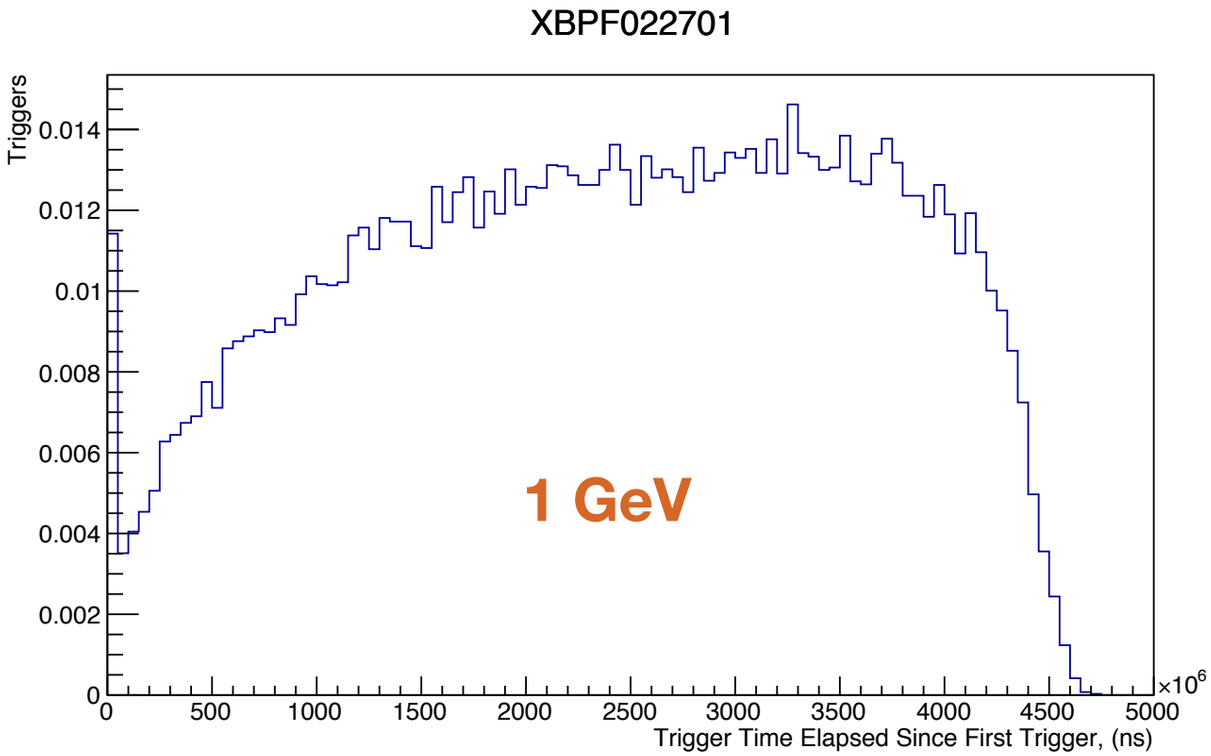
Contains all triggered events with 5 or more hits.

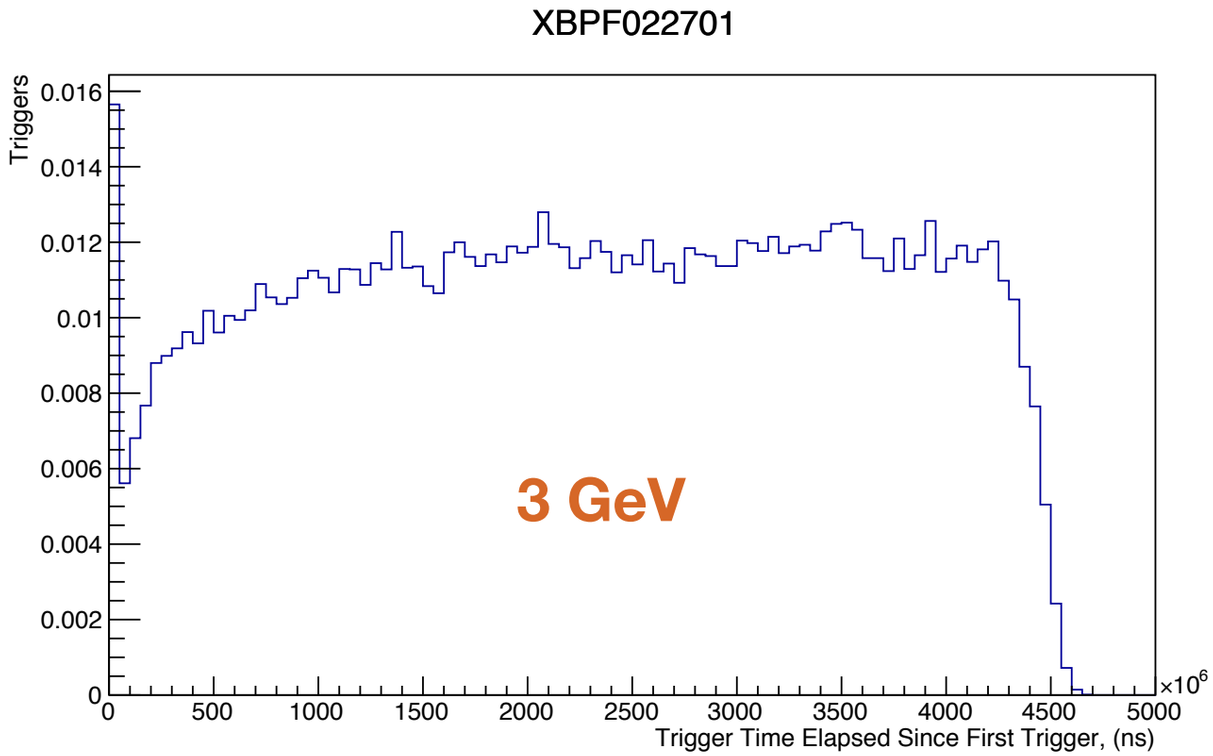


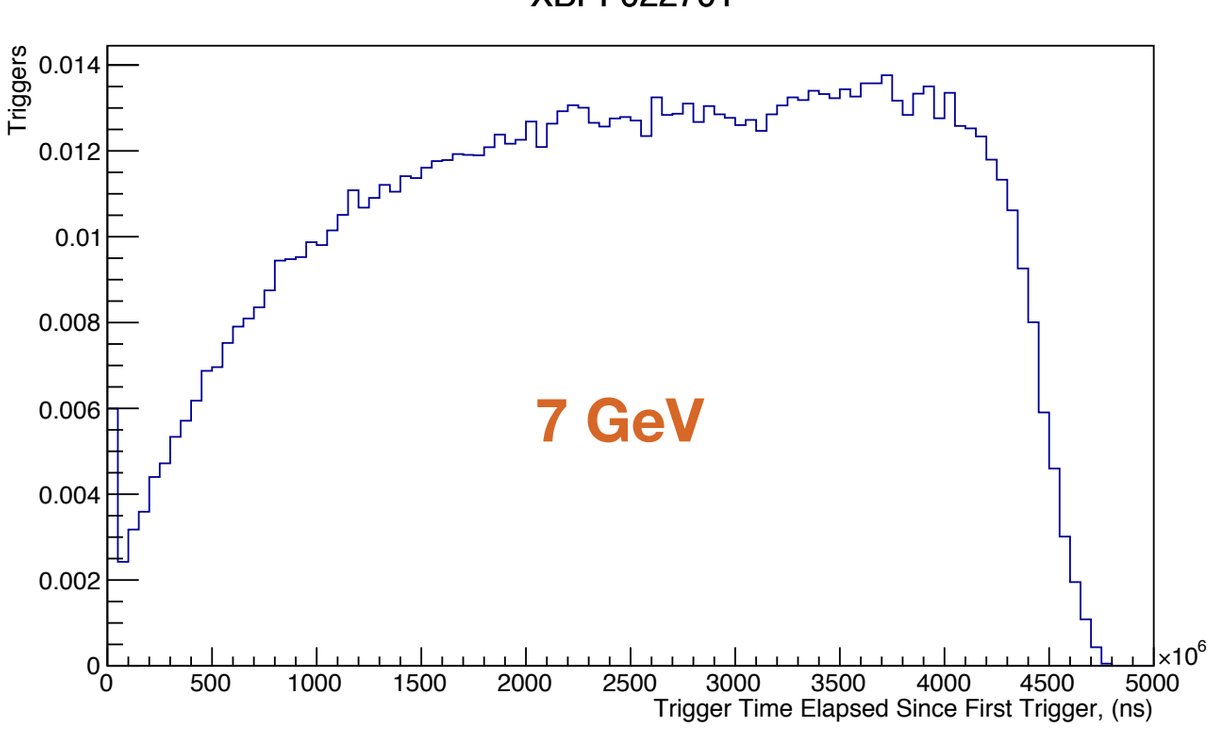
Efficiency = # triggered events with only 1 channel hit / total number of general triggers

Spill Shape

Can use time between any XBPF event in spill and first XBPF event in spill to see time profile of spill.





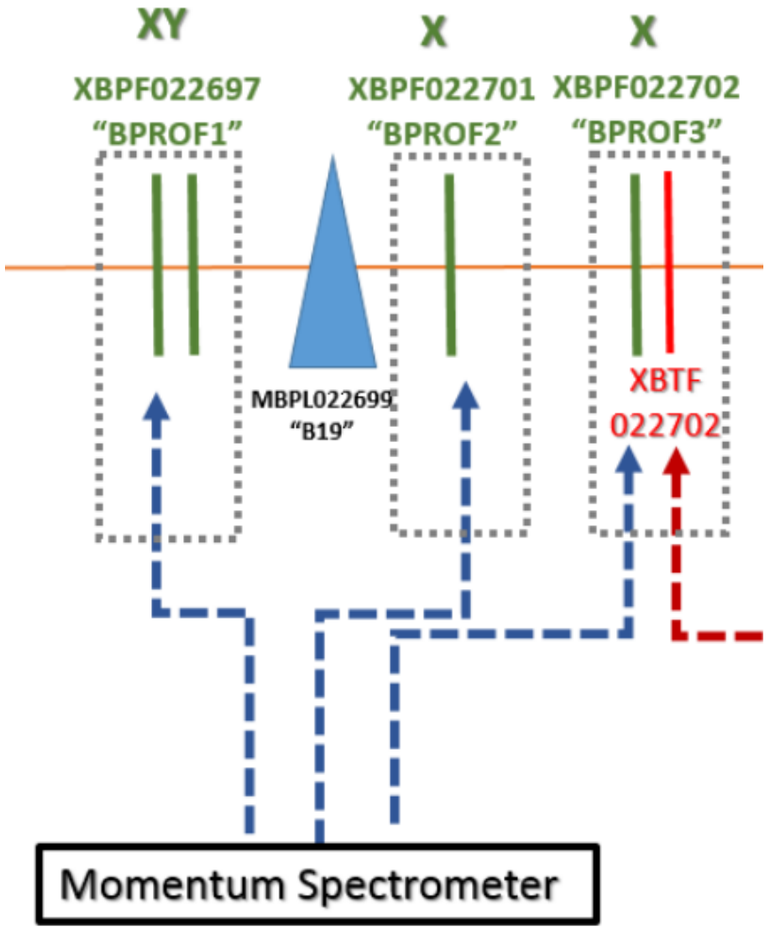


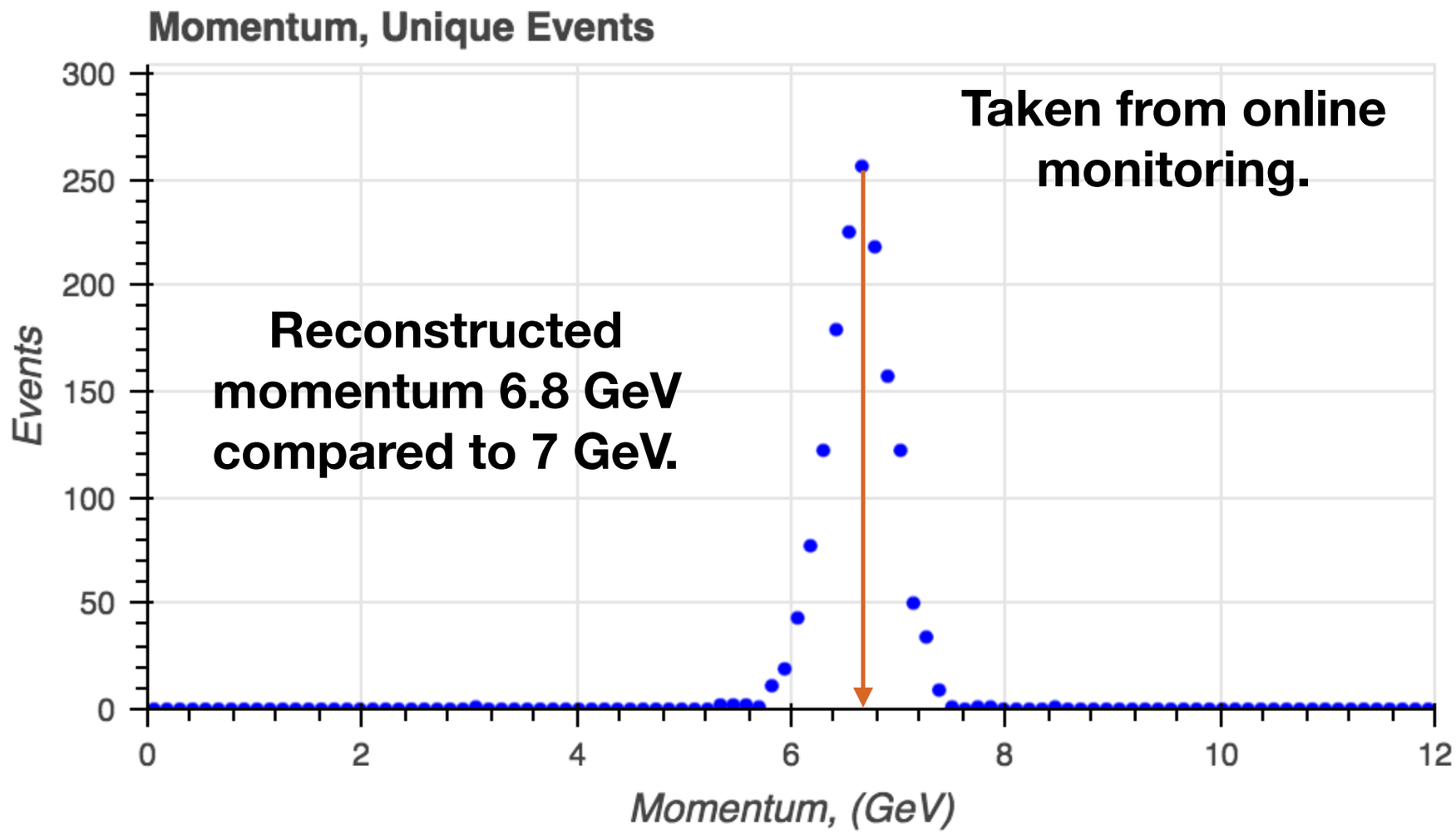
Pretty homogenous spill structure during extraction, as expected.

Momentum Spectrometer

Momentum Reconstruction

- Technique to reconstruct momentum int this way described in CERN note: **CERN-ACC-NOTE-2016-0052**.
- Based on using known value of magnetic field.
- These magnets used for many years at CERN. Magnetic field and BL -> I is known well.





Small inconsistency (< 5%) and behaviour systematic at all energies —> **transverse misalignment of fibre planes, one with respect to another.**

Similar problems and inconsistencies with this method see in past. (Nikos for details).

Still being investigated.

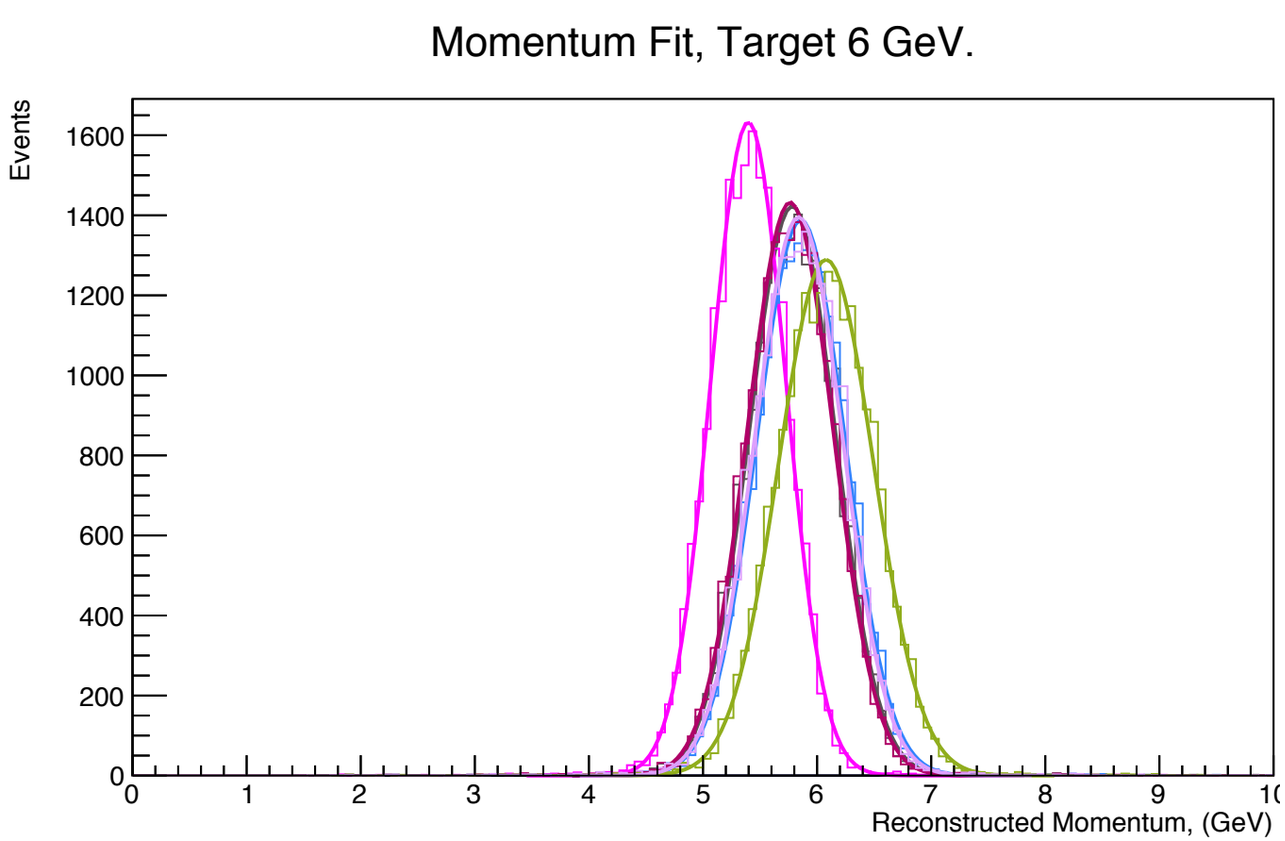
Quantifying Misalignment

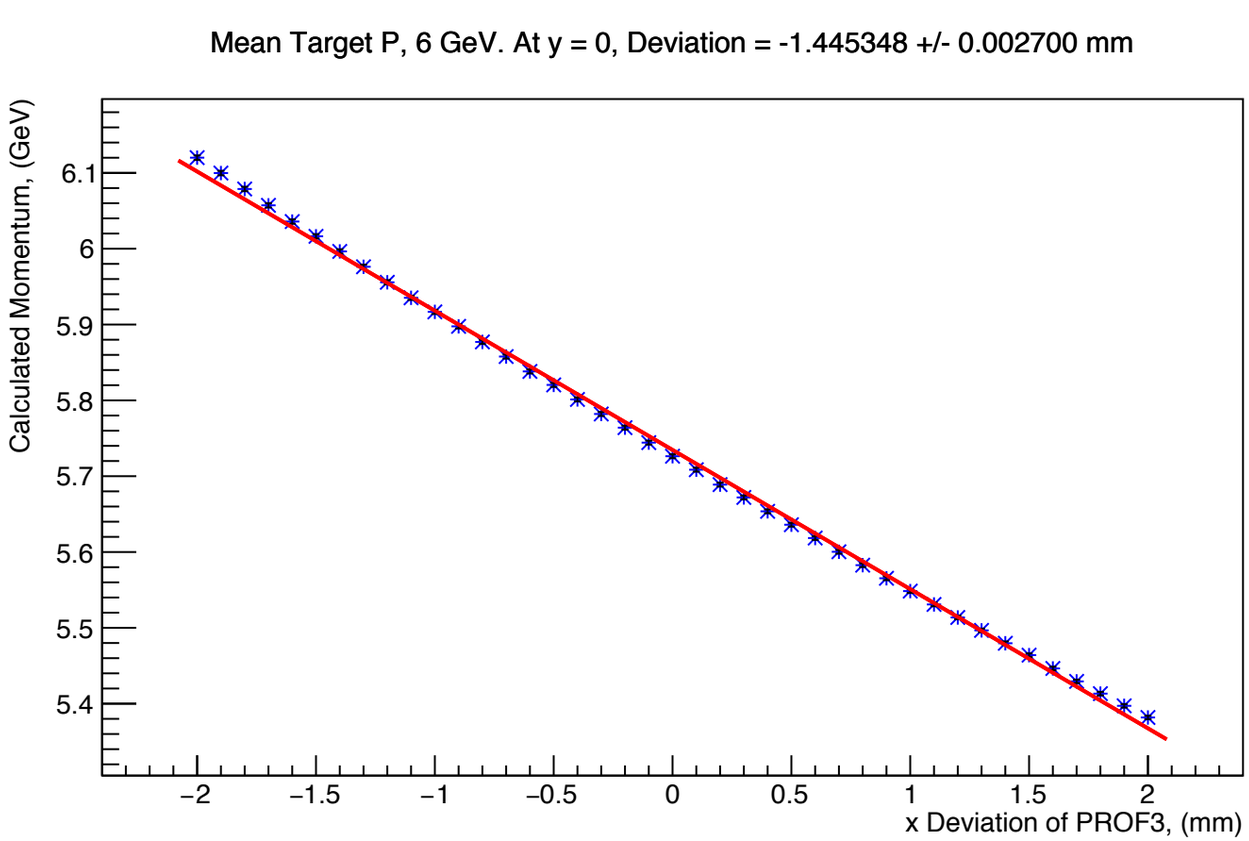
Marcel showed in MC that misalignment must be ~O(few mm).

1) Take raw data at various momenta.

2) Rerun momentum calculation with XBPF702 at various x positions, (+/- 2 mm every 0.1 mm around nominal).

3) Fit gaussian to momentum distributions.



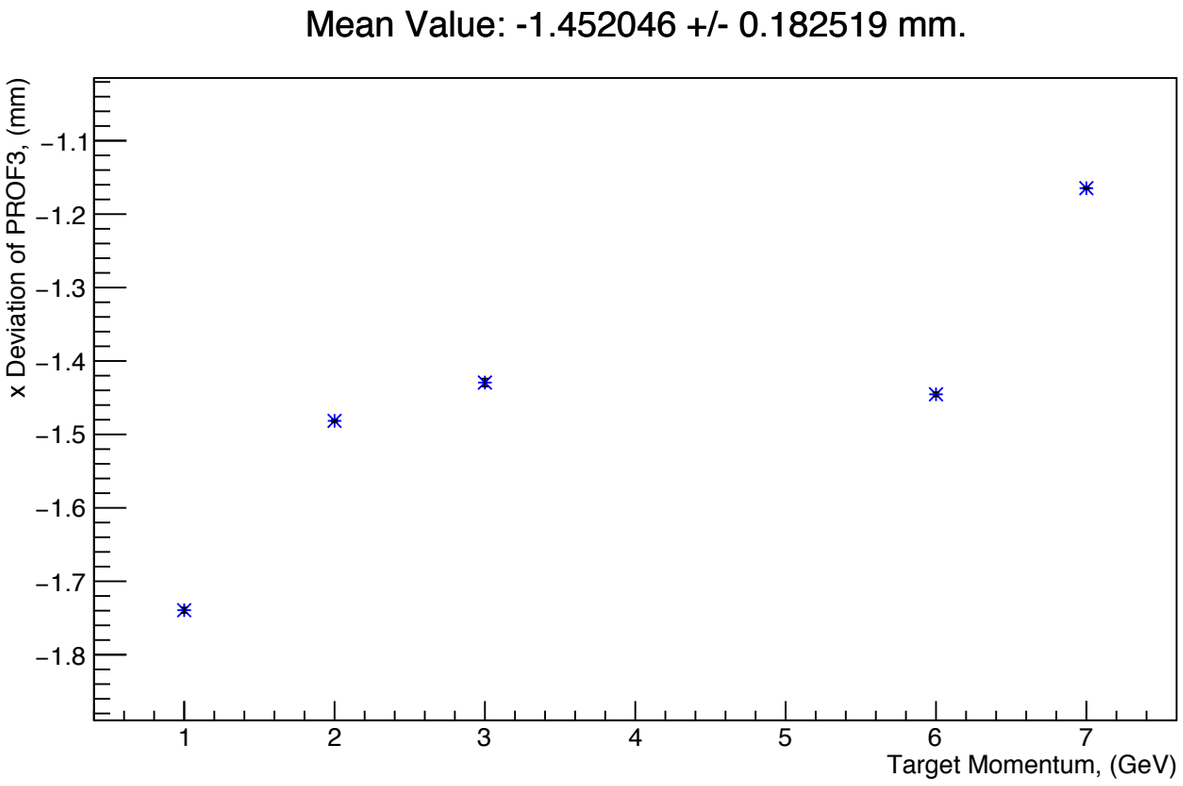


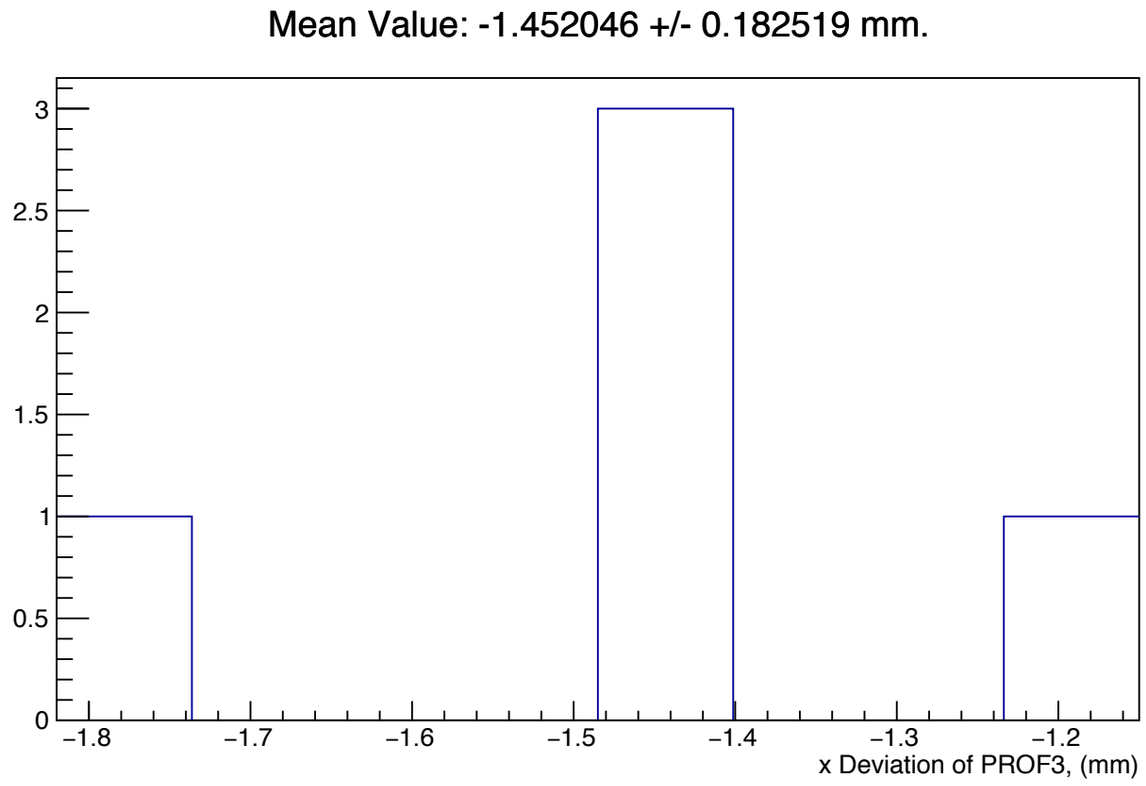
4) Plot mean of fits against corresponding deviation from nominal, make a linear fit.

5) Use fit line to calculate deviation that gives expect value of reconstructed momentum,

Quantifying Misalignment

Take the mean and standard deviation of these ‘best fit’ deviations.





‘Best fit’ across range of Momenta: -1.45 +/- 0.18 mm

Summary

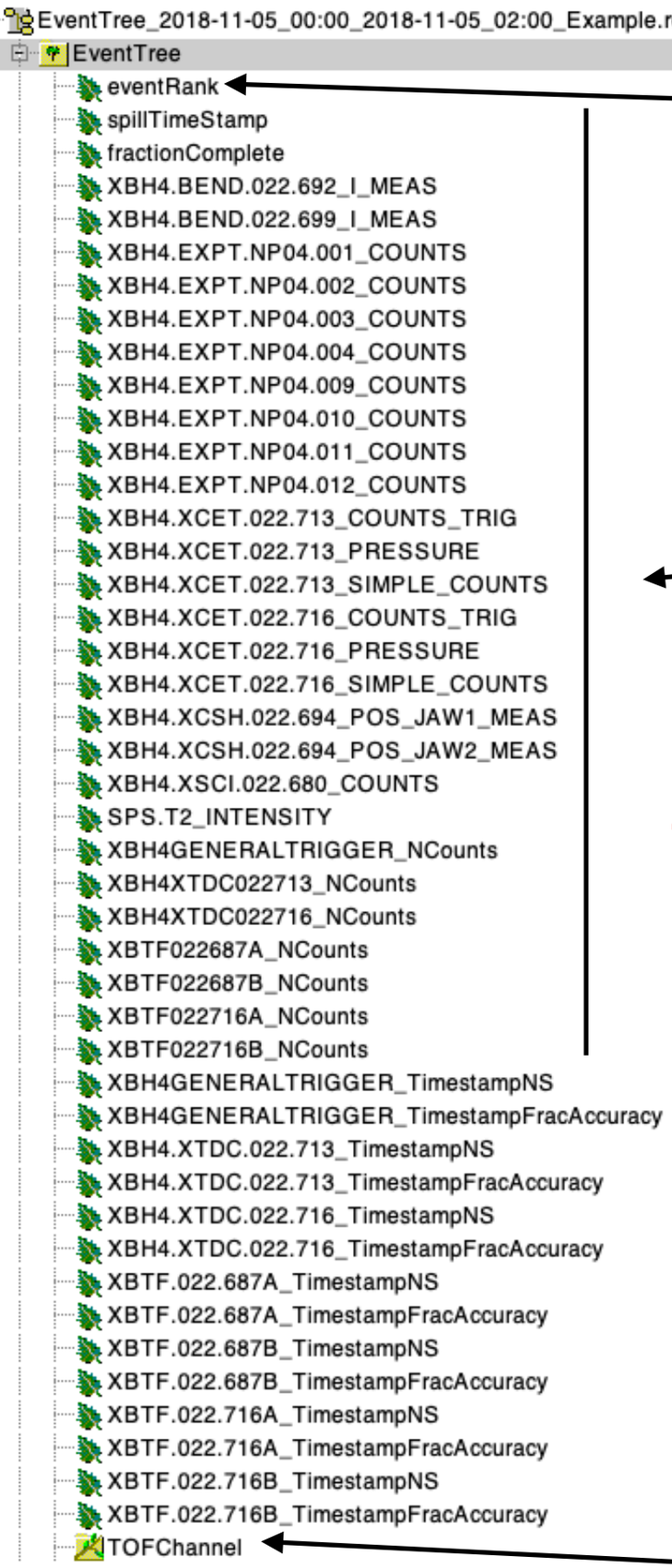
- Code to produce an off-line ‘event tree’ has been written. 1 entry <-> 1 general trigger.
- Written to ROOT file, making event-by-event analysis more straightforward.
- Chosen a good window (500 ns) around general trigger to look for events in BI. Will rerun analyses with 1000 ns, check for stability.
- Beam profiler (XBPF) efficiencies are as expected. Spill shape stable across various momenta.
- Systematically low reconstructed momenta can be account for with a 1.45 mm shift of 3rd profiler.

Put all data / results in EOS for use in momentum reconstruction and other ProtoDUNE offline.

Create these event trees for the data set of good runs? Per event record for the FNAL database, TPC timestamp, momentum, PID, quality flag etc.

Backup Slides

More of whats in the Tree I



Pick out ‘golden events’. To be worked on but for now, a rank 1 event is an event with a single hit in each of the XBPFs used for the momentum spectrometry and a unique time of flight matching to the general trigger.

For each event you can look at the spill level vars, for example what was the pressure in the Cherenkov’s when the data was taken, or what is the spill time of the spill the event is associated with.

1 entry = 1 event

Matched TDC times to general trigger (both XTOFs and XCETs). Frac is still there (although in nanoseconds) as 64 bit int is taken up entirely by the ns piece. If you want to use the frac accuracy you just add TimestampNS and TimestampFracAccuracy, but have to worry about what data type you do this calculation with. For user to decide.

TOF Channel of the event as string, eg AA, BA etc.

More of whats in the Tree II

TOF using full accuracy

Was a signal from each Cherenkov matched with the general trigger for the event.

Important information for all the XBPFs, e.g. how many fibres were hit, if multiple, what was the distance between them?

Human readable coordinates, not channel number.

Momenta for all possible combinations of hit channels.

How does it work?

- Pull all of the data out of Marcel's files, TDC timing info for each spill is contained within vectors, these are time ordered. The first entry in each of the general trigger vectors are therefore the first general trigger of each spill.
- Make a 'spill object' with this time and call it the spill time. I match spill level variables e.g. Cherenkov pressures by choosing the data who's timestamp is closest to this spill time.
- I then take the first time entry of each of the TDCs / XBPFs and compare to each spill time, taking the one which matches best.
- I now have a series of spill objects containing data which is split by spill, for example:

```
**********************************************************************************************************************************
*  SPILL INFO; TIMESTAMP S: 1541379584, NS: 0, NVARS ASSIGNED: 35/35.
**********************************************************************************************************************************
--------------------------------------------------------------------------------------------------------------------------------
- SPILL VARS:
SPS.T2:INTENSITY: 2499000000000, AT TIME 1541379579s 735000000ns.
XBH4.BEND.022.692:I_MEAS: 206.40000000000000056843419, AT TIME 1541379319s 335000000ns.
XBH4.BEND.022.699:I_MEAS: 206.19999999999999886313162, AT TIME 1541379579s 735000000ns.
XBH4.EXPT.NP04.001:COUNTS: 8295, AT TIME 1541379589s 176000000ns.
XBH4.EXPT.NP04.002:COUNTS: 6645, AT TIME 1541379589s 176000000ns.
XBH4.EXPT.NP04.003:COUNTS: 8692, AT TIME 1541379589s 176000000ns.
XBH4.EXPT.NP04.004:COUNTS: 5637, AT TIME 1541379589s 175000000ns.
XBH4.EXPT.NP04.009:COUNTS: 323143, AT TIME 1541379579s 735000000ns.
XBH4.EXPT.NP04.010:COUNTS: 2499, AT TIME 1541379579s 735000000ns.
XBH4.EXPT.NP04.011:COUNTS: 284, AT TIME 1541379579s 735000000ns.
XBH4.EXPT.NP04.012:COUNTS: 119, AT TIME 1541379579s 735000000ns.
XBH4.XCET.022.713:COUNTS_TRIG: 119, AT TIME 1541379588s 975000000ns.
XBH4.XCET.022.713:PRESSURE: 3.5849869999999999923716132, AT TIME 1541379588s 975000000ns.
XBH4.XCET.022.713:SIMPLE_COUNTS: 87, AT TIME 1541379588s 975000000ns.
XBH4.XCET.022.716:COUNTS_TRIG: 119, AT TIME 1541379588s 975000000ns.
XBH4.XCET.022.716:PRESSURE: 1.2204749999999999997655209, AT TIME 1541379588s 975000000ns.
XBH4.XCET.022.716:SIMPLE_COUNTS: 13, AT TIME 1541379588s 975000000ns.
XBH4.XCSH.022.694:POS_JAW1_MEAS: -43.899999999999999857891453, AT TIME 1541379584s 489000000ns.
XBH4.XCSH.022.694:POS_JAW2_MEAS: 43.899999999999999857891453, AT TIME 1541379584s 489000000ns.
XBH4.XSCI.022.680:COUNTS: 589503, AT TIME 1541379588s 999000000ns.

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- XBPFs:
XBH4.XBPF.022.697:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.698:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.701:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.702:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.707:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.708:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.716:EVENTSDATA AT TIME: 1541379584
XBH4.XBPF.022.717:EVENTSDATA AT TIME: 1541379584

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- XTDCs:
XBH4.GENERALTRIGGER AT TIME: 1541379584
XBH4.XTDC.022.713 AT TIME: 1541379584
XBH4.XTDC.022.716 AT TIME: 1541379583
XBTF.022.687A AT TIME: 1541379584
XBTF.022.687B AT TIME: 1541379584
XBTF.022.716A AT TIME: 1541379584
XBTF.022.716B AT TIME: 1541379584
**********************************************************************************************************************************
```

Spill time

How many devices / vars have we managed to match?

Spill level vars matched.

XBPFs matched

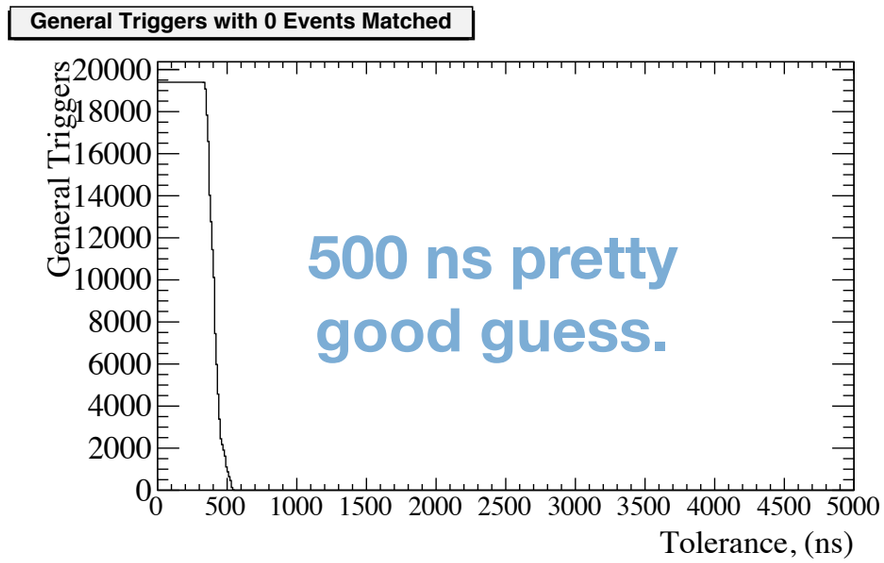
XTDCs matched

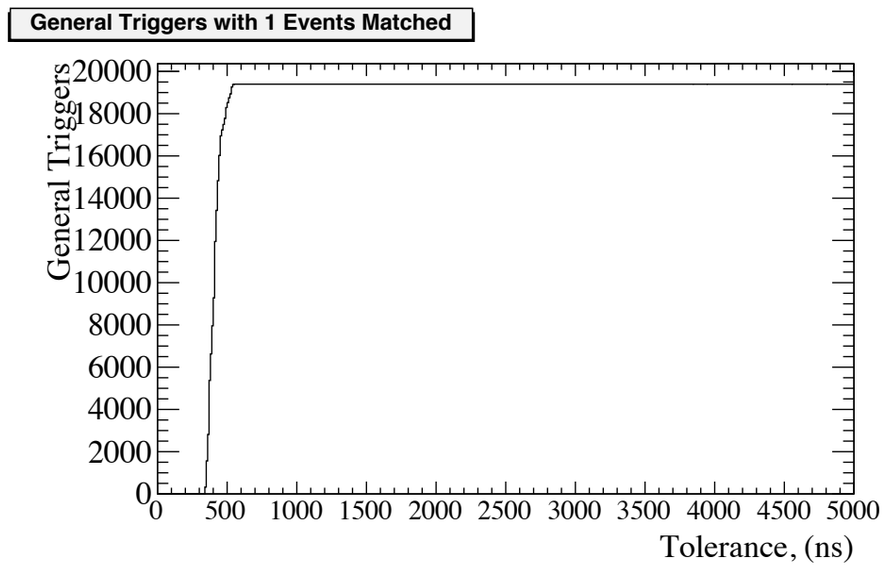
How does it work?

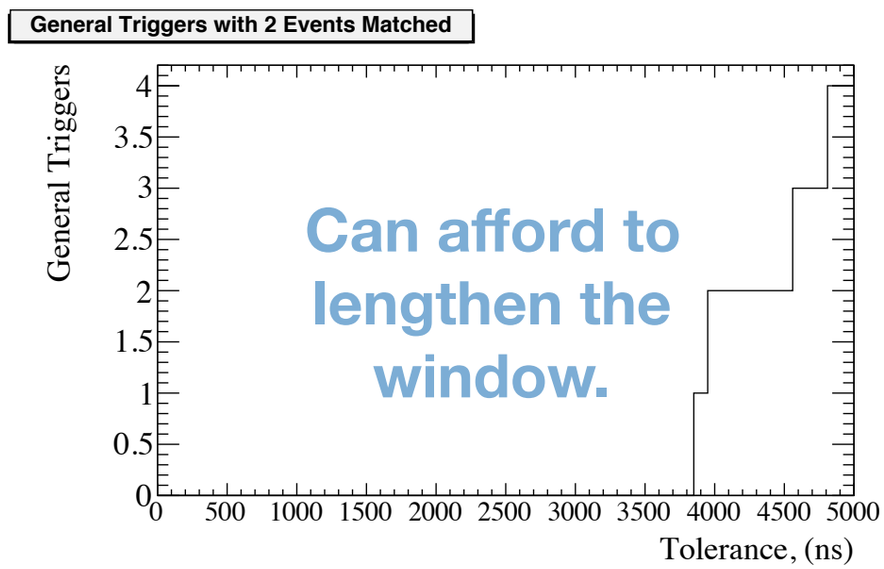
- Within each spill I then loop through the events in each TDC / XBPF and match the event times to the general triggers with NS precision (which is enough given event rates) given some tolerance.
- Tolerance is currently 500ns, sometimes you get multiple possible TDC associations with the general trigger. I keep a record of this and such events can be discarded using a eventRank flag.
- When a Cherenkov fails to be matched to a general trigger, this means there was no light and this fact is recorded.

x Projection: XBPF

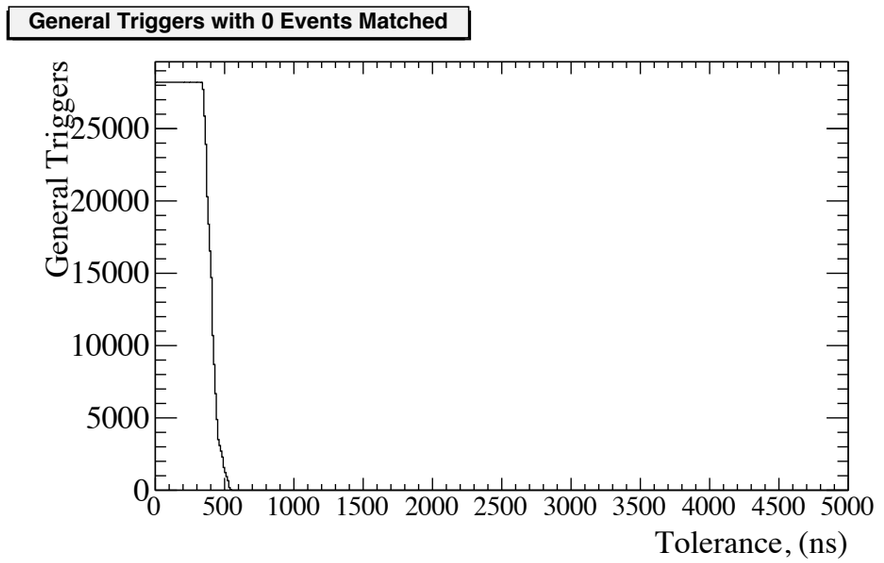
XBPF, 1 GeV

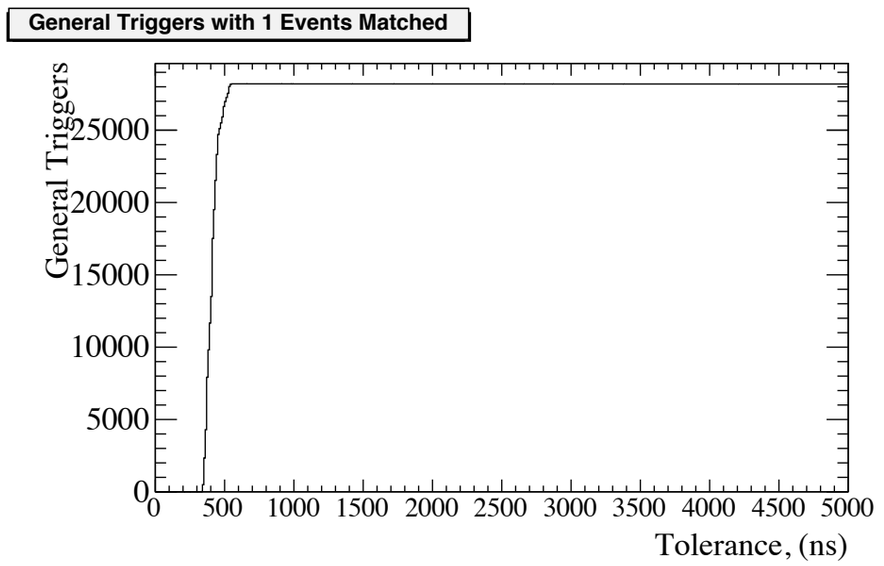


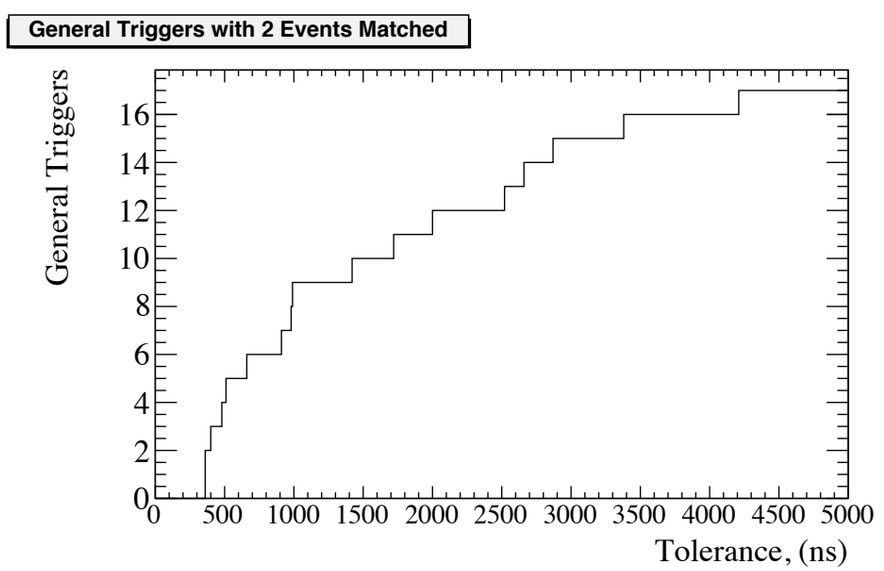




XBPF, 6 GeV

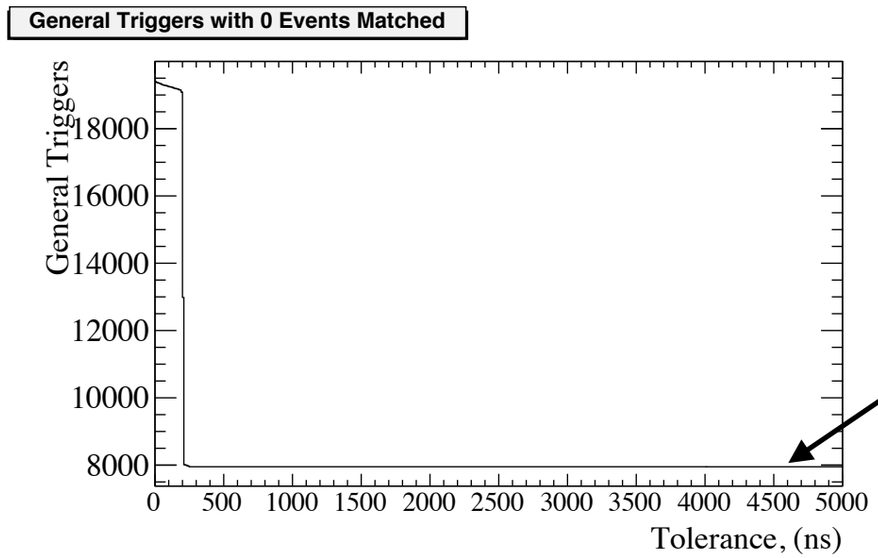


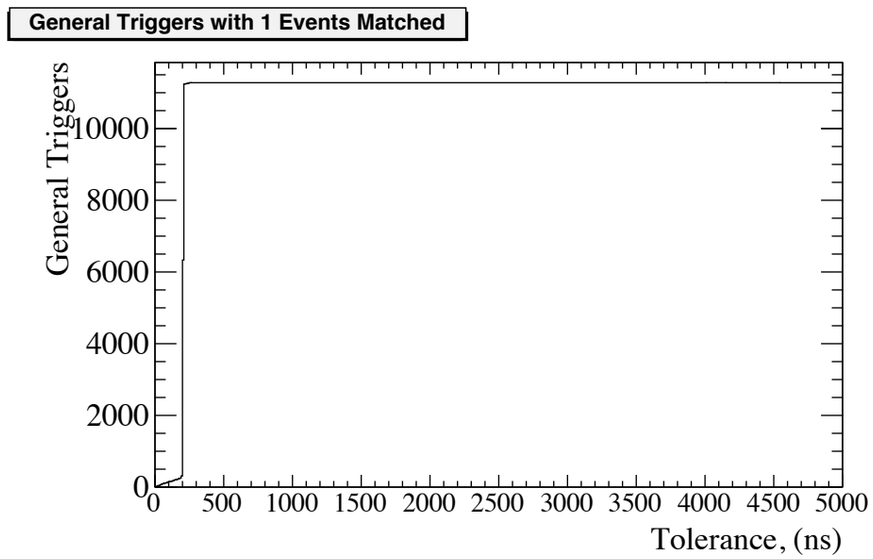


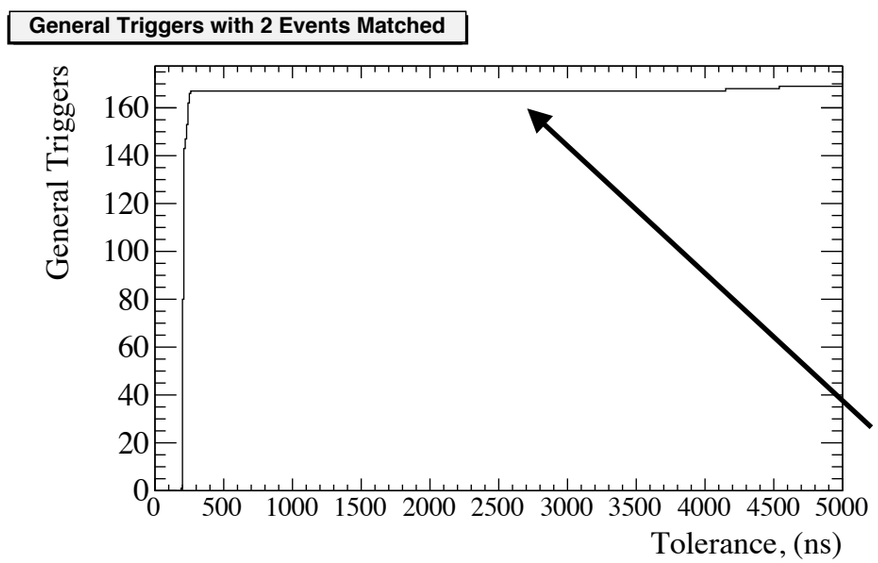


x Projection: XBTF

XBTF, 1 GeV



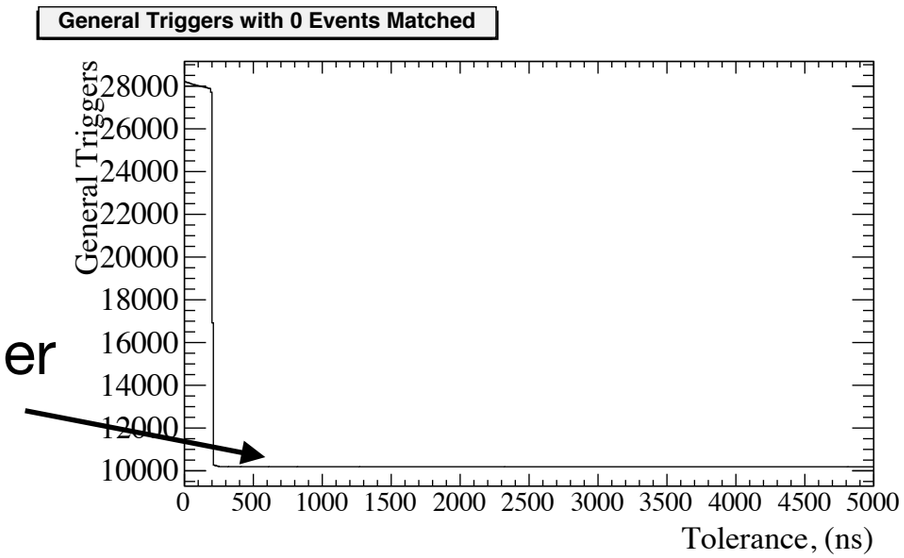


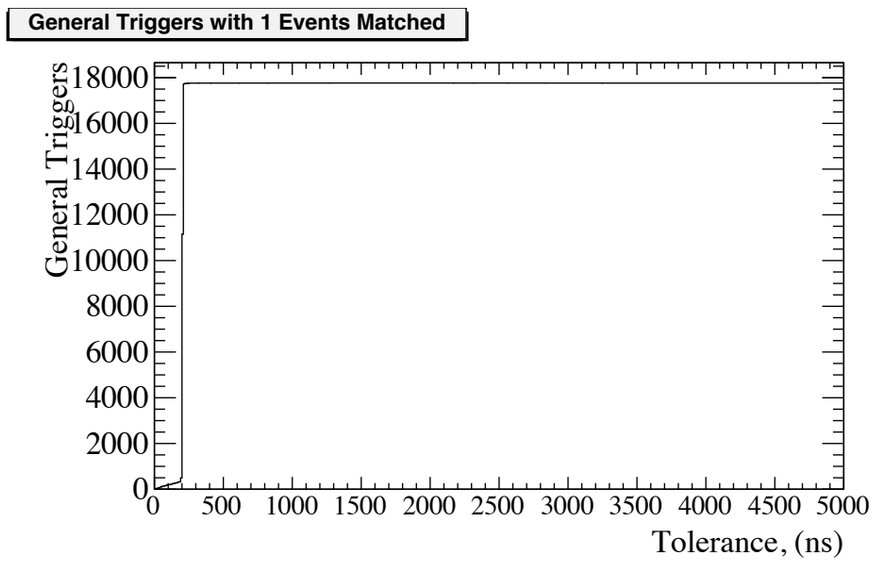


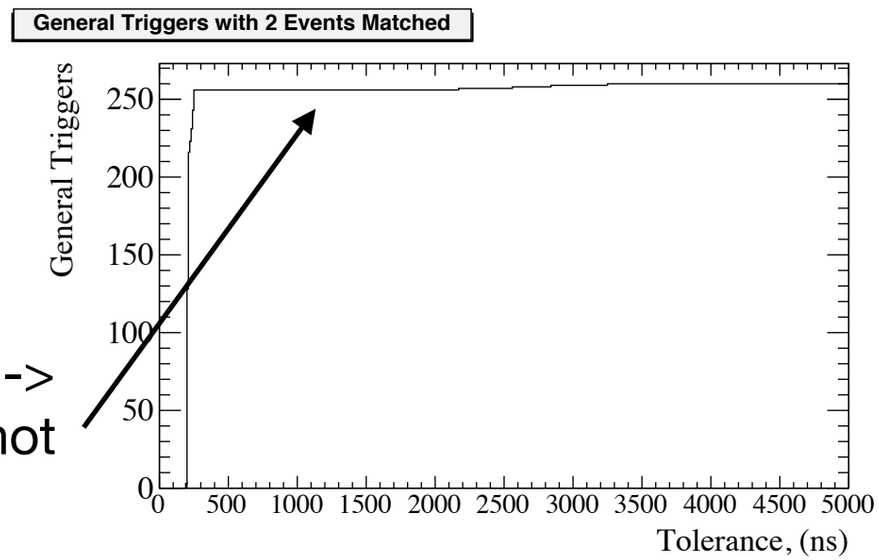
Though other XBTF.

Not triggered -> more events not matched

XBTF, 6 GeV







PID & Beam Composition Logic

At 1 & 2 GeV, with 1 bar can only see electrons.

XCET 713 ~ 0.1 bar (low), XCET 716 ~ 1 bar (high).

Signal from XCET 716 -> electron. No signal -> mu/pi/K/proton.

Check TOF. TOF > Mean + 4 sigma -> proton. Else mu/pi/K.

At 3 GeV 1.2 bar, see only electrons. At 3.5 bar see mu / pion / electron. Never see K or P.

XCET 713 ~ 3.4 bar (high), XCET 716 ~ 1.2 bar (low).

Signal from XCET 716 -> electron.

Signal from XCET 713, nothing from XCET 716 -> mu / pion.

Nothing from either -> K or P. Check TOF. TOF > Cut -> proton. Else K.

At 6 GeV 1.5 bar, see e / mu / pi, never K or P. At 9 bar e / mu / pi / K.

XCET 713 ~ 9 bar (high), XCET 716 ~ 1.5 bar (low).

XCET 713, 0 and XCET 716, 1 -> e / mu / pi.

XCET 713, 0 and XCET 716, 0 - > proton.

XCET 713, 1 and XCET 716, 1 -> e / mu / pi / K.

XCET 713, 1 and XCET 716, 0 -> K.